

Kuzbass Botanical Garden climate characteristics and the state of the environment

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Abstract. The characteristic of a number of parameters variability of the Kuzbass Botanical Garden climate are studied for the period from 1966 to 2020. An indirect assessment of the climate based on the climate biological efficiency index is given. The analysis of the long-term dynamics of the selected parameters is carried out, the main temporal patterns in their distribution are revealed. As initial materials, air temperature and precipitation daily data for the period 1966-2020.

1 Introduction

Botanical gardens solve such important problems as the development of scientific foundations and methods of gene pool of natural and cultural flora protection and preservation, introduction and acclimatization of plants. In addition, under artificial conditions, collections of living plants (especially rare and endangered species) and other botanical objects, having great scientific, educational, economic and cultural significance, are created and preserved. The successful implementation of these botanical gardens activities depends on their sustainability and the state of the environment.

At present, during the period of an intensive shift of the global climate towards warming, especially on the regional level, the ecological environment on the territories of botanical gardens - with numerous collections of rare and endangered plants species from various geographic regions - is changing significantly.

Under these conditions, it becomes necessary to estimate the weather and climatic conditions changes, and, ultimately, the vulnerability (sustainability) of territories to the impacts of climate change. On this basis, appropriate additional adaptation measures for new environmental conditions, arising due to the current global warming, can be developed and taken. All the problems mentioned above are relevant for the Kuzbass Botanical Garden as well.

The Kuzbass Botanical Garden collections of the natural flora plants have been formed since 2002. The first samples were brought from the Scientific Research Institute of Siberian Horticulture, named after M.A. Lisavenko, Barnaul City; from the Central Siberian Botanical Garden, Novosibirsk City; from the Altai Botanical Garden, Rider City. Since 2003, the collections have been replenished due to the samples collected by the Botanical Garden scientists during expeditionary research, mainly in the Siberian region, as well as due to the seeds and living materials exchange with other Russian botanical gardens.

In total, the collections contain about 700 species of natural flora plants, including 46 species listed in the Red Book of the Kemerovo Region and 12 species listed in the Red Book of Russia [3].

The ecological conditions of the Kuzbass Botanical Garden flora objects preservation are determined by the peculiarities of the forest-steppe landscape, that is distinguished by the complexity of the composition and structure as a transitional zonal type, as well as a relatively unstable regime of physical and geographical processes, especially weather and climatic ones. Actually, each component or element of the landscape, especially the climate as a whole or its elements (precipitation, wind, etc.), as well as relief, soil cover, etc., can be taken separately as an object of environmental assessment, in the meaning of its positive or negative impact degree on native flora or introduced plants. Nevertheless, the ecological effect of a particular natural factor depends on its combination with other factors - for example, a lack of heat or moisture can completely neutralize the positive effects of all the other factors.

Thus, the assessment of environmental factors should be comprehensive, i.e. encompass their entire totality, embodied into the concept of the landscape ecological potential. The complexity of such an assessment is determined by the need to take into account tens or even hundreds of different parameters and by the impossibility of finding a quantitative measure of their integral ecological effect. A comparative assessment of the landscape ecological potential is based on a few defining criteria and, first of all, on the ecologically obligatory ones, i.e. irreplaceable and constantly influencing factors, the absence of which reduces the landscape ecological potential to zero, as without them life is just impossible. First of all, these are warmth and moisture [5].

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2 Materials and Methods

The most of other landscape ecological parameters depend on the amount and ratio of heat and moisture, including the adaptability of "emigrant" plants to local ecological conditions. In the practice of scientific research, a certain conditional ratio measure of the landscape heat and moisture reserves is taken as a starting point for the ecological potential ranking. It was empirically found, that the index of climate biological efficiency, proposed by N.N. Ivanov [4], must be taken as the most valid indicator (at least for the temperate climatic zone conditions). The values of this index are well correlated with other important indicators of the landscape ecological potential, including the annual duration of the optimal temperature period, biogeochemical conditions, the intensity of the biological cycle of substances, the annual production of phytomass, various natural phenomena, etc.

As an indicator of the ecological and climatic background sustainability of the Kuzbass Botanical Garden, the index of the climate biological efficiency was calculated. This indicator is an integral criterion for heat and moisture supply, it is the multiplication of the sums of active temperatures over 10 °C in hundreds of degrees ($0.01 * T > 10 \text{ }^\circ\text{C}$) by the moisture coefficient:

$$TC=0,01*\sum T10*MC, \quad (1)$$

MC is calculated as the ratio of the annual precipitation (P, mm) to the annual evaporation (Eo, mm), which is obtained by summing the evaporation values for each month of the year (E), calculated by the formula (2):

$$E=0,0018*(25+T)^2*(100-h), \quad (2)$$

where T is the average monthly air temperature, °C; h is the average monthly relative air humidity, %.

The physical meaning of the climate biological efficiency index reflects the conditions for the maximum possible development of the vegetation cover with a combination of the optimal amount of heat and moisture. The value of the index equal to 22 is the most close to the optimum.

3 Results and Discussion

The initial data for calculating the Kuzbass Botanical Garden climate efficiency index was the daily values of the following meteorological parameters: monthly average, seasonal, as well as their values of individual stages critical for plants, and annual air temperatures, precipitation and relative humidity. On their basis, the annual sums of temperatures above 0 and 10 °C, the sums of atmospheric precipitation, as well as complex indicators were calculated: evaporation [E], moisture coefficient (MK) and index of the climate biological efficiency (TK). To calculate the selected meteorological parameters, we used observational data with a daily resolution from the ... base, collected from 1966 to 2020 (55 years period) at the Kemerovo station, agro, located in 12 km to the South from the Kuzbass Botanical Garden. The long-term variation of meteorological parameters was studied with methods of statistical analysis and calculation of linear trend coefficients with an assessment of their significance.

The analysis shows that during the study period, there is an increase of almost all the parameters under consideration – except the relative air humidity (Table 1).

Table 1. Statistical characteristics of meteorological parameters of the Kuzbass Botanical Garden in the period from 1966 to 2020 (according to data from the Kemerovo station, agro).

Parameter	Average	Minimum (annual)	Maximum (annual)	KH.IT (°C/10 years)	b*	R ²
Average annual temperature, °C	1.0	*-2.2 (1969)	3.7 (2020)	0.49	0.37	0.341
The sum of average daily temperatures higher than 0°C	2417.5	2073 (1972)	2790 (2020)	69.89	2222	0.468
The sum of average daily temperatures higher than 10°C	2019.8	1621 (1972)	2374 (2020)	64.8	1838	0.304
Annual precipitation amount, mm	491.5	326.4 (1981)	658.2 (2013)	23.26	426.4	0.238
Annual evaporation, mm	537.0	415.6 (1985)	701.1 (2012)	17.67	487.5	0.227
Relative humidity, %	73.4	69.5 (1976)	76.2 (1985)	-0.019	74	0.034
Moisture coefficient	0.8	0.28 (2012)	1.36 (2013)	0.015	0.89	0.017
Climate biological efficiency	14.9	6.4 (1966)	26.2 (2007)	0.87	16.2	0.169

One of the necessary ecological and climatic tasks is the assessment of the growing season thermal regime. To characterize the ecological and climatic conditions, not only their average values are important, but also the sums of the accumulated average daily air temperatures, which have a direct impact on the overall development of plants and on their development in concrete phases.

In the long-term view, all the considered thermal parameters have a positive trend (Table 1). It is noteworthy that the minimum values were recorded at the time stage of the 60 – 70s, i.e. before the stage of intense climate warming at the end of the XX – beginning of the XXI century, and the maximum values were noted in the phase of the highest climate warming at the beginning of the XXI century.

Among these parameters, the most intensive increase is in the sums of average daily temperatures higher than 0 °C, than the sums of average daily temperatures higher than 10 °C. Such differences occur due to a reduction of the cold period at its beginning (later start) and at the end (earlier completion). The coefficients of determination R² show that the trends are statistically significant. The main reason for the revealed trend in the growth of average and total temperatures is a steady increase in air temperatures in all months of the year in the range of years 1966 – 2020.

The thermal conditions and the increase of various temperature parameter lead to the increased moisture evaporation. The amount of evaporation directly affects the moisture supply, and, consequently, the ecological conditions of the moisture consumption by the plants of the Kuzbass Botanical Garden.

Under the climate changing conditions, the study of the precipitation regime is of undoubted interest. The variability of the annual amounts of atmospheric precipitation is similar to the long-term temperature change – a clear positive trend is observed. In contrast to precipitation, the dynamics of relative humidity has a weak negative trend, but its reliability has not been confirmed.

Complex parameters of moisture (evaporation, moisture coefficient) have a positive trend, that ultimately affects the climate biological efficiency changes characteristics (Table 1).

The climate biological efficiency index synthesizes the most important hydrometeorological elements: precipitation, air temperature and relative humidity, that characterizes the annual heat and moisture supply and validly describes the general ecological background [5].

Depending on the value of the climate biological efficiency index, there exist different interpretations of the environment ecological conditions. Thus, the authors [1, 5] identified the level of ecological potential or the scale of ecosystem sustainability (Table 2).

Table 2. The level of ecological potential and the scale of stability of geosystems depending on the gradation of the climate biological efficiency index

The value of the biological effectiveness index	The level of ecological potential [1]	Geosystems stability scale [5]
0 – 8	Very low	the most volatile
08 – 12	Low	volatile
12 – 16	Averagerelatively high	moderately resistant
16 – 20	Relatively high	resistant
20 и более	High	The most resistant

We have analyzed the temporal changes of the climate biological efficiency index (fig.). The average value of this index for the Kuzbass Botanical Garden is 14.9. The spread of the values over time is significant: from 6.4 in 1966 and 1998 to 26.4 in 2007.

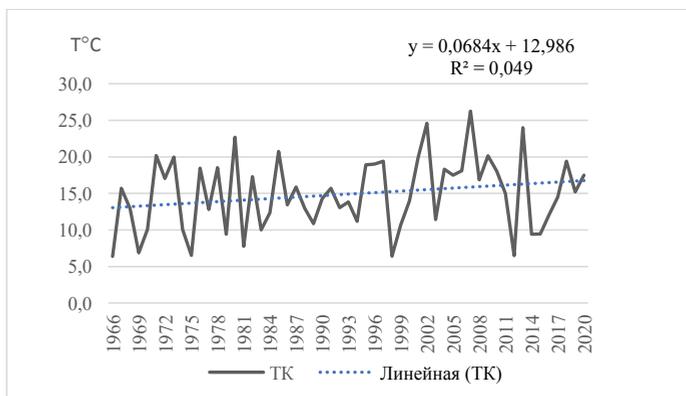


Fig. Long-term variation of the climate biological efficiency index in the Kuzbass Botanical Garden.

Over a 55-year period (1966 – 2020), 16 years (29.1%) have been allocated as years with unstable level of the climate biological efficiency (with TC values from 0 to 12). The number of years with a stable level, with a TC value equal to or more than 12, is 39 years (56.4%). Among them, the majority of years is characterized by a moderately stable (29.1%) and sustainable (27.3%) level of climate efficiency.

4 Conclusion

Thus, the current state of the environment on the regional level is becoming unstable. Long-term changes in the climate biological efficiency, as a complex indicator of the environment of the Kuzbass Botanical Garden, have a positive trend. However, in some years, the efficiency index can have both a low or unstable level of environmental potential, or rather high. For the introduction and acclimatization of plants, as well as for the creation and preservation of living plants (especially rare and endangered species) and other botanical objects collections in artificial conditions, it is necessary to take into account the peculiarities of current environmental changes.

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